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**US Army Edgewood Arsenal  
Chemical Research and Development Laboratories  
Technical Report**

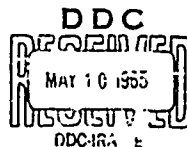
**CRDLR 3254**

**Protection Afforded by Experimental XXCC3-Impregnated  
Navy Work/Combat Clothing Worn by  
Men Exposed to Mustard Vapor**

by

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Nelson P. Musseiman  
Clyde H. Graf  
George A. Trapp  
Paul B. Dawson

February 1965



**EDGEWOOD ARSENAL, MARYLAND 21010**

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PROTECTION AFFORDED BY EXPERIMENTAL XXCC3 IMPREGNATED NAVY  
WORK/COMBAT CLOTHING WORN BY MEN EXPOSED TO MUSTARD VAPOR

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February 1965

US ARMY EDGEWOOD ARSENAL  
CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES  
EDGEWOOD ARSENAL, MARYLAND 21010

## FOREWORD

This work was authorized under Project 1C622401A097, Medical Defense Aspects of Chemical Agents (U), Task 1C622401A09701, Investigation and Evaluation of Protective Equipment (U), conducted under Directorate of Medical Research approved Research Plan 5043. Work was funded in part by the US Naval Supply Research and Development Facility, Navy Supply Center, Bayonne, N. J., Bureau of Supplies and Accounts, Department of the Navy, subtask 80-02-001-002-1-1-1-3, MIPR 920-7215164, 2 March 1964. The work was started in June 1964 and completed in August 1964. The experimental data are contained in notebook 1C622-401 A097.

## Acknowledgments

The authors acknowledge the cooperation of Lt Col Nicholas Buttigieri and Mr. Carl Searn from Clinical Research Division in providing the volunteers, the volunteers for their service, Mr. Marshall F. Gilchrist, Mr. John Deppisch, S/Sgt Arne Rosquist, Sp5c Walter Hunter, Mr. Thomas Mitchell, and Pfc William Konzal, from Physical Protection Division, for suggestions offered and for the proper fitting of protective masks and clothing on the subjects. The technical assistance of Pfc Donald Swan from Vapor Toxicity Branch in the analysis of mustard vapor is acknowledged. The authors are also grateful to Mr. Elmo Maiolatesi for fabrication of the mustard dispersion bubbler, to Dr. Harold Averill, Coordinator of Research and Protection, Directorate of Medical Research, and to Mr. Maurice Weeks, Vapor Toxicity Branch, and Mr. Edward Cherowier, of the US Naval Supply Research and Development Facility, for helpful suggestions.

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### DIGEST

The effectiveness of Navy protective clothing (single-layer type) impregnated with XXCC3 against mustard vapor (20 mg/cu m) was tested by 10 men. Two men serving as controls wore the standard Army two-layer XXCC3-treated protective clothing and were exposed with the group. When mustard vapor penetrated the Navy clothing, erythema developed at the site of penetration within 24 hr after exposure. When this occurred, the affected subject was withdrawn from further exposure tests. The men were exposed for 15 min on the first day, 30 min on the second day, and for 1 hr on each of the following 8 days. Erythema was produced on 9 of the 10 men wearing Navy clothing exposed in the cumulative Ct range of 3,306 to 10,054 mg min/cu m, with corresponding cumulative exposure times varying between 2.75 and 8.35 hr. Most of the erythema occurred in the abdominal area. The one remaining Navy suit and the two control Army suits did not break during the 10 exposures, which totaled cumulative Ct's of 10,500 mg min/cu m and 8.75 hr.

Considerable care in size selection and adjustment of the Navy clothing outfit on the wearers was necessary to assure the absence of gaps in protection over the forearms and around the waist.

It is concluded that the experimental XXCC3-impregnated Navy work/combat clothing can be worn by men in mustard vapor for a cumulative Ct of 7,000 mg min/cu m (total time 6 hr) without incapacitating effects.



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PROTECTION AFFORDED BY EXPERIMENTAL XXCC3-IMPREGNATED NAVY  
WORK/COMBAT CLOTHING WORN BY MEN EXPOSED TO MUSTARD VAPOR

I. INTRODUCTION.

The US Army Edgewood Arsenal Chemical Research and Development Laboratories were requested to furnish the necessary services, personnel, facilities, and supplies required for the evaluation of experimental YXCC3-impregnated Navy work/combat clothing. The purpose of this evaluation was to determine whether these garments fulfill the requirements as protective suits against chemical agents. The garments were evaluated by exposing volunteers to mustard vapor in a chamber.

II. EXPERIMENTATION.

A. Materials and Equipment.

Chloropicrin was utilized in the leak testing of the protective masks worn by the volunteers. The mustard was plant-distilled and its purity reported to be from 95% to 98%.

The clothing was supplied by the US Naval Supply Research and Development Facility, Navy Supply Center, Bayonne, N. J. The complete protective outfit consisted of a shirt, trousers, hood, socks, cotton gloves, plastic booties, and plastic gloves. All of the items of clothing except the plastic gloves and booties were impregnated with XXCC3. The shirts were fabricated from 6, 2-oz nylon-cotton poplin and were of a pullover type. They were worn on the outside of the trousers and were drawn tight at the bottom with a drawcord. The trousers and hood were made from 8.8-oz nylon-cotton sateen. The socks and cotton gloves were standard items and were worn over the trouser legs and shirt sleeves. The hood had a front and back bib and an inner circular protective flap attached to the neckline. It had two drawstring adjustments, one at the forehead and another on the inner neck flap, to prevent vapor entrance. The bib was designed to cover the front opening of the shirt. To complete the Navy outfit, each man wore the Mk V gas mask.

These Laboratories supplied unimpregnated shorts, T-shirts, and untreated leather Army combat boots. The two control subjects wore the standard US Army two-layer XXCC3-impregnated clothing for comparison. Figures 1 to 8 illustrate the Navy and Army clothing as in these tests in different stages of dressing.



FIGURE 2

NAVY TROUSERS, SOCKS,  
AND SHOES DONNED



FIGURE 1

SUBJECTS WEARING NAVY UNIMPREGNATED T-SHIRT  
AND .HCR TS (LEFT) AND ARMY IMPREGNATED  
LONG UNDERWEAR (RIGHT)



FIGURE 3

NAVY JACKET WORN OVER T-SHIRT



FIGURE 4

NAVY GLOVES DONNED, HOOD SLUNG  
AROUND NECK PRIOR TO FITTING



FIGURE 5

NAVY GAS MASK DONNED, FRONT AND  
BACK VIEW OF HOOD IN PLACE



FIGURE 6

FRONT VIEW OF COMPLETELY  
DRESSED SUBJECTS

Left - Arr - clothing  
Right - Navy clothing including plastic  
boots over boots



FIGURE 7

REAR VIEW OF COMPLETELY  
DRESSED SUBJECTS

Left - Army clothing

Right - Navy clothing

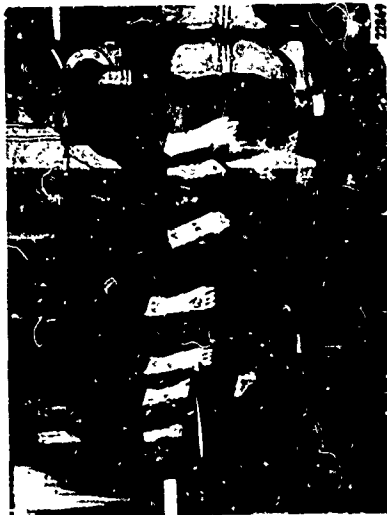


FIGURE 8

SUBJECTS LEAVING GASSING CHAMBER

(Last individual is wearing Army  
clothing as control)

B. Procedures for Chamber Operation and Analysis of Mustard-Vapor Concentration.

A 20-cu m dynamic gassing chamber was used in the mustard tests. The airflow was 5,000 l/min. Dry nitrogen was passed through the liquid mustard at 114°C in a specially designed bubbler (figure 9) at a rate of approximately 2 l/min to give a chamber concentration of 20 mg/cu m.

The mustard concentration in the chamber was determined on samples of chamber air by a bromine titration method using the modified Northrup manual electrolytic titrimeter.<sup>1</sup> A sample was collected and analyzed every 3 min. The cumulative Ct's were determined during the progress of an exposure.

C. Subjects.

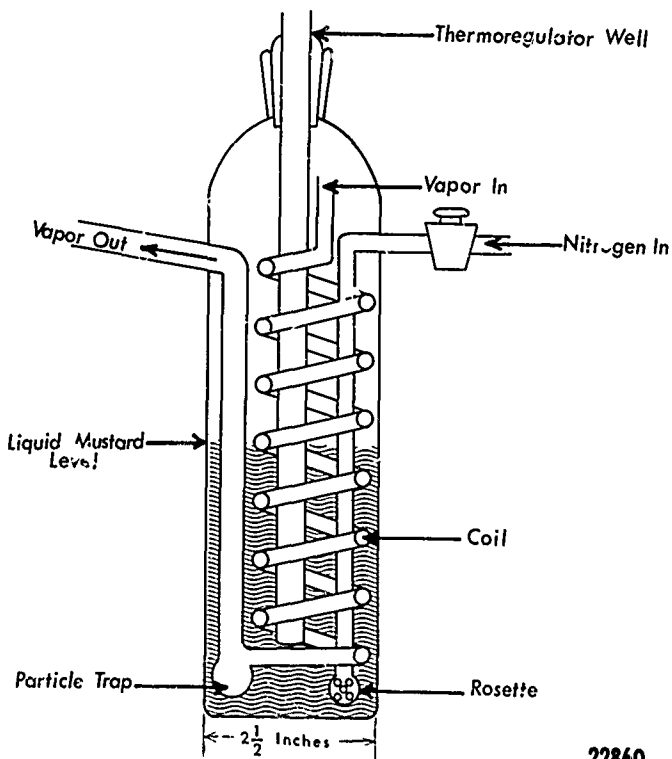
1. Selection and Use.

The volunteers selected for this study were made available by the Clinical Research Division. They were divided into two groups (A and B) of six men each, five wearing the Navy clothing and one wearing the Army control clothing. For the first eight exposures, group A was exposed in the morning and group B in the afternoon. In the ninth and tenth exposures the men from both groups who had not developed erythema (totaling five men in this instance) were exposed as one group. No exposures were made on Saturdays or Sundays. Each subject had previously been examined by a physician (figure 10) for skin rash and other dermatological conditions that might mask the mustard effect if a clothing break and erythema were to occur.

2. Dressing and Preparation of Subjects for Mustard Test.

The subjects were dressed by clothing specialists to assure proper wearing of the clothing and proper fitting of the protective mask and hood. Amyl acetate vapor from a bottle of the liquid was applied to the periphery of the mask to check for gross leaks. A further mask-leakage test was made by exposing the men to chloropicrin in a gassing chamber.<sup>2</sup> In the chamber a series of physical exercises was performed for 5 min to ascertain that the mask was properly fitted and would not leak while being worn in mustard vapor.





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FIGURE 9  
BUBBLER FOR DISPERSING MUSTARD VAPOR



FIGURE 10

EXAMINATION OF SKIN BY PHYSICIAN PRIOR TO EXPOSURE

### 3. Exposure of Subjects to Mustard.

The procedure for exposure to mustard vapor is similar to that previously described.<sup>3,4</sup> After the chloramine test, the men entered the mustard chamber and remained for a period of 15 to 60 min. The men were exposed daily to mustard vapor at increasing Ct's ( $C = 20 \text{ mg/cu m}$ ,  $t = 15$  to 60 min), but not exceeding 1,218 mg min/cu m any one day. No man received more than 10 exposures or a maximum cumulative Ct of 10,500 mg min/cu m. The men were instructed to leave the chamber if they detected, or thought they detected, an odor of mustard. During the exposure, each man was in full view of the observers and in contact with them by an intercommunication system. The temperature of the exposure chamber was 24° to 27°C (average 25°C), and the relative humidity was 58% to 70% (average 65%). The men were allowed freedom of movement during exposure, but they were requested not to sit down or lean against the chamber walls. During the final 15 min of the last eight exposures, the men were directed to walk in a circle and to step on and off an 8-in.-high concrete block approximately twice per minute to flex the clothing further.

To assure the safety of the subjects, a physician was in attendance. After the mustard exposure, the men remained in the anteroom 4 min to aerate their clothing. They were then escorted outside for an additional 20 min aeration. They were assisted by clothing experts in removing their contaminated clothing. The clothing was hung in a well-ventilated room until the next exposure day. After a shower, observation, and a discussion of the day's proceedings, the men were dismissed.

Twenty-four hours after each exposure, a physician carefully examined the subject for mustard effects. If erythema was seen, the subject was withdrawn from further exposures, and the cumulative Ct was considered the breaking point for that particular garment.

#### D. Mustard-Vapor-Penetration Tests.

Samples of cloth were cut from the Navy protective clothing before and after the clothing was exposed to mustard vapor in the wearing trials. These samples were tested for concentration of chloramide as free chlorine<sup>5</sup> and for mustard penetration ( $\mu\text{g/sq cm}$ ) under standard conditions by the Dawson Agent Test apparatus.\* The results were compared with those for the Army 8.5-oz, one-layer, XXCC3-impregnated sateen fabric.

\* Dawson, P. B. Procedure for Testing Mustard Vapor Penetration Through Fabrics. Unpublished Directive from Clothing and Decontamination Branch, CRDL. January 1, 1963.

The general procedure for the mustard-penetration test is as follows: Mustard vapor (20 to 25 mg/cu m at 80% relative humidity, dry-bulb temperature 90°F) is drawn through test fabric at a velocity of 10 cm/min for 6 hr, with intermittent penetration samples being collected in bubblers at 0 to 2 hr and 2 to 6 hr. The effluent mustard concentration is analyzed by the DB3 method<sup>a</sup> and expressed as micrograms per square centimeter for the collection time indicated.

### III. RESULTS.

Table 1 shows the daily exposure time and the cumulative Ct for each of the two groups of subjects. The longest cumulative exposure time was 8.75 hr, with an average cumulative Ct exposure of 10,500 mg min/cu m. Table 2 gives the number of exposures to mustard vapor and the cumulative Ct exposure values for clothing breaks after which erythema was observed.

No erythema was seen in either of the two subjects wearing the standard Army impregnated ensemble or in one subject wearing the impregnated Navy clothing for 10 days, the duration of the test. Nine Navy suits broke between cumulative Ct's of 3,300 and 10,000 mg min/cu m. The first one broke after the fourth exposure. Another broke on the fifth day, three on the seventh day, two on the eighth day, and two on the tenth day.

The erythema usually was present on the abdominal or chest area close to the waistline. In one man it was present on the scrotum, and in two men it was present about the groin and trigonal area.

Table 3 shows average values for samples from Navy unexposed and exposed clothing items evaluated in the laboratory for chloramide content and mustard-vapor penetration. The mustard tests did not appreciably deplete the chloramide content of the fabric, and the penetration of mustard through the fabric was not appreciably altered by the wearing trials. Laboratory tests showed that the nylon-cotton Navy and Army sateen fabrics are comparable in chloramide content and in protection provided.

<sup>a</sup> Dawson, P. B. Op. cit.

TABLE 1

DAILY EXPOSURE TIMES AND CUMULATIVE Ct'S RECEIVED BY  
 SUBJECTS WEARING TEST CLOTHING IN MUSTARD VAPOR

Exposure day	Group A (morning)			Group B (afternoon)		
	Exposure time	Ct	Cumulative Ct	Exposure time	Ct	Cumulative Ct
	min	mg min/cu m		min	mg min/cu m	
1st	15	294	294	15	303	303
2nd	30	606	900	30	585	888
3rd	60	1,206	2,106	60	1,206	2,094
4th	60	1,200	3,306	60	1,200	3,294
5th	60	1,218	4,524	60	1,212	4,506
6th	60	1,200	5,724	60	1,206	5,712
7th	60	1,200	6,924	60	1,206	6,918
8th	60	1,200	8,124	60	1,194	8,112
9th	60	1,188	9,312	60	1,188	9,300
10th	60	1,194	10,506	60	1,194	10,494
Total exposure time	8.75 hr			8.75 hr		

TABLE 2  
NUMBER OF EXPOSURES TO MIN. ARD VAPOR AND CUMULATIVE Ct'S PRIOR  
TO CLOTHING BREAK, AS INDICATED BY OCCURRENCE OF ERYTHEMA

Subject number	Number of exposures	Cumulative exposure time hr	Cumulative Ct mg min/cu m	Report of physician's exam 24 hr after last exposure
A. Army Clothing (Controls)				
6A	10	8.75	10,506	No erythema
6B	10	8.75	10,494	No erythema
B. Navy Clothing				
4A	4	2.75	3,306	Erythema (4- X 8-in.) on midabdomen ab e umbilicus
4B	5	4.5	5,424	Mild erythema (3- X 3-in.) on upper chest about breast
1B	7	5.75	6,918	Moderate erythema at beltline
2B	7	5.75	6,918	Moderate erythema (8- X 8-in.) on anterior abdomen
7B	7	5.75	6,918	Moderate erythema in trigonal area and about beltline
1A	8	6.75	3,124	Erythema about groin
5A	6	6.75	3,124	Erythema on abdomen
2A	10	8.35	10,054	Erythema (8- X 12-in.) with one vesicle on abdomen, erythema under chin (approximately 1- X 2-in.)
3A	10	8.35	10,054	Moderate erythema on scrotum, with burning sensations
5B	10	8.75	10,494	No erythema

TABLE 1  
LABORATORY EVALUATION OF NAVY PROTECTIVE CLOTHING BEFORE AND AFTER  
CLOTHING WAS EXPOSED TO MUSTARD VAPOR IN WEARING TRIALS

Clothing items sampled	Chloramide content as (free chlorine (average))			Mustard-vapor penetration of fabric (average)				
	Number of samples*	mg/sq cm		Number of samples*	Samples taken 0 to 2 hr		Samples taken 2 to 6 hr	
		Unexposed clothing	Exposed clothing		Unexposed clothing	Exposed clothing	Unexposed clothing	Exposed clothing
					pg/sq cm			
Hood	2	0.765	0.585	3	0.3	0.3	0.6	0.7
Jacket	2	0.460	0.385	3	1.0	0.6	1.3	1.1
Trousers	2	0.564	0.481	3	0.4	0.4	0.8	0.9
Army 8.5-oz treat - eastern	1	0.600	0.570	1	0.06	0.07	1.6	1.6

\* For each condition; i.e., unexposed and exposed clothing.

#### IV. DISCUSSION.

The type of protective clothing used in the Navy study was the so-called one-layer system. Only the outer layer was impregnated; the underwear was the standard unimpregnated T-shirt and shorts. In contrast, the Army clothing used as a control consisted of two layers of clothing; both the outer garment and the long-sleeved undershirt and long-legged underpants were impregnated. It would be unreasonable to expect a one-layer system to afford more protection than a two-layer system. Mustard vapor penetrates by slipping through the treated fabrics and through inadequacies of closures; i.e., cuffs, collar, etc.

Although the Navy one-layer suit was inferior to the Army two-layer suit in protection against mustard vapor, it was considered to be safe for a wearing period of at least 1-3/4 hr without resulting in burns. This represents a mustard vapor cumulative Ct of 2,100 mg min/cu m for three wearing trials. The erythema noted in the first individual occurred from a cumulative exposure above this Ct and below 3,306 mg min/cu m. The second person to receive a burn acquired it between cumulative exposures of 3,300 and 5,400 mg min/cu m. The burns in these two subjects were quite mild and were not incapacitating. Those burns merely indicate that an endpoint had been approached. In fact, one-half of the men (five) did not develop erythema until a Ct of 7,000 mg min/cu m or higher was reached. Figure 11 shows three subjects with burns on the abdomen.

Laboratory tests for chloramide content and mustard penetration of fabric suggest that the protection afforded by the suits did not deteriorate after mustard exposures, but that the resulting erythema was primarily a cumulative effect of the slight slipping that occurred over a period of time. No doubt, if another individual wore the same suit and were exposed, he would not develop erythema before the Ct that caused erythema in the previous wearer was reached.



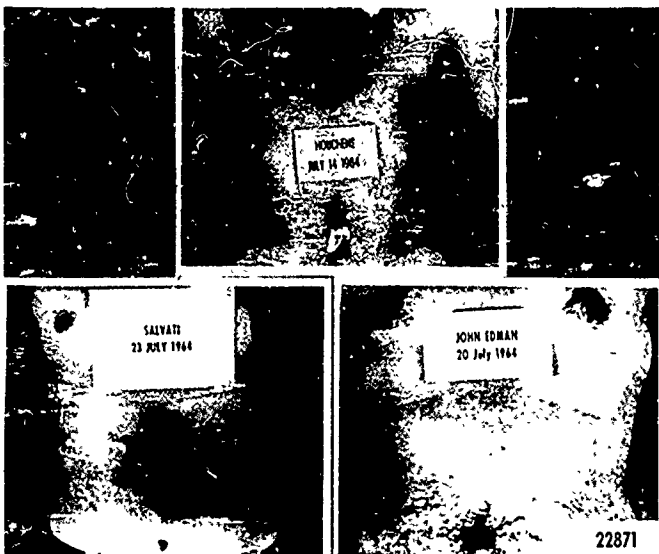


FIGURE 11

ENDPOINT OF CLOTHING PROTECTION RESULTING IN ER: THEME  
IN SUBJECTS EXPOSED TO MUSTARD VAPOR

(Top, subject 4A; bottom left 2A; bottom right, 1A)

Several comments may be made as to the fitting of the clothing, although this probably had no bearing on the mustard burns. Attempt was made to fit the proper-sized uniform to the man according to his height and weight, as indicated on Army TECOM 8-4-6230 (M's Sizing and Fitting Worksheet). Some suits, which should have been satisfactory according to the labeled size and the worksheet, were much too small, and it was necessary to substitute a larger suit. In particular, the sleeves were very short and the cuff closing gapped (figure 3), making it difficult to seal. The long white protective gloves were intended to cover the gap in the sleeves. When this was not possible, a shirt with longer sleeves was substituted. In all cases it was necessary to pin the glove cuff to the sleeve above the gap. The neck portion of the hood also was very tight and tended to pull the mask off the face when the subject pushed his head forward. The inner circular protective flap on the under side of the hood was considered unnecessary in a test of this nature. The flap was not placed under the shirt as designed (figures 5 and 6).

#### V. CONCLUSION.

It is concluded that the experimental XXCC3-impregnated Navy work/combat clothing can be worn by men in mustard vapor for a cumulative Ct of 7,000 mg min/cu m (total time 6 hr) without incapacitating effects.

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UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D																														
(Security classification of title, body of abstract and indexing annotations must be entered when the overall report is classified)																														
1. ORIGINATING ACTIVITY (Corporate author) US Army Edgewood Arsenal Chemical Research and Development Laboratories, Edgewood Arsenal, Maryland 21010 Toxicology, Chemical Research, and Physical Protection Division		2a. REPORT SECURITY CLASSIFICATION <u>UNCLASSIFIED</u> 1b. GROUP																												
3. REPORT TITLE PROTECTION AFFORDED BY EXPERIMENTAL XXCC3-IMPREGNATED NAVY WORK-COMBAT CLOTHING WORN BY MEN EXPOSED TO MUSTARD VAPOR																														
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) The work was started in June and completed in August 1964																														
5. AUTHOR(S) (Last name, first name, initial) Oberat, Fred W.                      Musselman, Nelson P.                      Graf, Clyde J. Trapp, George A.                      Dawson, Paul B.																														
6. REPORT DATE February 1965	7a. TOTAL NO. OF PAGES 25	7b. NO. OF REFS 5																												
8a. CONTRACT OR GRANT NO.	8b. ORIGINATOR'S REPORT NUMBER(S)  c. (DLR 3254  d. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A																													
9. PROJECT NO. 1C622401A097																														
10. AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314																														
11. SUPPLEMENTARY NOTES Medical defense aspects of chemical agents		12. SPONSORING MILITARY ACTIVITY None																												
13. ABSTRACT The protective effectiveness of Navy protective clothing (single-layer type) impregnated with XXCC3 was tested by exposing 10 men wearing the outfit in an atmosphere of mustard vapor (20 mg/cu m). Ten men serving as controls wore the standard Army two-layer XXCC3-treated protective clothing and were exposed with the group. The men were exposed for 15 min on the first day, 30 min on the second day, after which the daily exposure time was 1 hr on the following 8 days. When mustard vapor penetrated the Navy clothing, erythema developed at the site of penetration within 24 hr after exposure. When this occurred the affected subject was withdrawn from further exposure tests. Erythema was produced on nine of the ten men wearing Navy clothing exposed in the cumulative Cf range of 3,506 to 10,054 mg min/cu m, with corresponding cumulative exposure times varying between 2 1/2 and 8 1/2 hr. Most of the erythema occurred in the abdominal area. The remaining one Navy suit and the two control Army suits did not break during the 10 exposures totaling cumulative Cf's of 10,500 mg min/cu m and 8 75 hr. The Navy clothing outfit required considerable care in size selection and adjustment on the wearers to assure the absence of gaps in protection over the forearms and around the waist. It is concluded that the experimental XXCC3-impregnated navy work/combat clothing can be worn by men in mustard vapor for a cumulative Cf of 7,000 mg min/cu m (total time 6 hr) without incapacitating effects.																														
14. KEYWORDS <table border="0"> <tr> <td>XXCC3</td> <td>Exposures</td> <td>Impregnated clothing</td> <td>Cf range</td> </tr> <tr> <td>Wearing trials</td> <td>Mustard vapor</td> <td>Work-combat clothing</td> <td>Must chamber</td> </tr> <tr> <td>Navy clothing</td> <td>Incapacitation</td> <td>Chloroamide-treated</td> <td></td> </tr> <tr> <td>Penetration</td> <td>Concentration</td> <td>Single-layer clothing</td> <td></td> </tr> <tr> <td>Cumulative Cf</td> <td>Combat-work clothing</td> <td>Human investigation</td> <td></td> </tr> <tr> <td>Verdicts</td> <td>Protective clothing</td> <td>Two-layer clothing</td> <td></td> </tr> <tr> <td>Impregnation</td> <td>Clothing trials</td> <td>Army clothing</td> <td></td> </tr> </table>			XXCC3	Exposures	Impregnated clothing	Cf range	Wearing trials	Mustard vapor	Work-combat clothing	Must chamber	Navy clothing	Incapacitation	Chloroamide-treated		Penetration	Concentration	Single-layer clothing		Cumulative Cf	Combat-work clothing	Human investigation		Verdicts	Protective clothing	Two-layer clothing		Impregnation	Clothing trials	Army clothing	
XXCC3	Exposures	Impregnated clothing	Cf range																											
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Navy clothing	Incapacitation	Chloroamide-treated																												
Penetration	Concentration	Single-layer clothing																												
Cumulative Cf	Combat-work clothing	Human investigation																												
Verdicts	Protective clothing	Two-layer clothing																												
Impregnation	Clothing trials	Army clothing																												

DD FORM 1473

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UNCLASSIFIED  
Security Classification

PROTECTION AFFORDED BY EXPERTIZAL XXCC3-IMPREGNATED NAVY WEAR  
COMBAT CLOTHING WORK BY MEN EXPOSED TO MUSTA J VAPOR

US ARMY EDGEMOOD ARSENAL  
CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES

Technical Report CRDLR 3654

February 1955

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